UNITED STATES DISTRICT COURT

DISTRICT OF ARIZONA

In Re Bard IVC Filters Products Liability Litigation	No. MD-15-02641-PHX-DGC

EXHIBIT INDEX

PLAINTIFFS' RESPONSE TO DEFENDANTS C. R. BARD, INC.'S AND BARD PERIPHERAL VASCULAR, INC.'S MOTION TO EXCLUDE THE OPINIONS OF DEREK MUEHRCKE, M.D.

Exhibit 1	ACR SIR SPR Practice Parameter (**FILED UNDER SEAL**)
Exhibit 2	Tillman Deposition Excerpts 8-4-16
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EXHIBIT 1

Revised 2016 (Resolution 17)*

ACR–SIR–SPR PRACTICE PARAMETER ON INFORMED CONSENT FOR IMAGE-GUIDED PROCEDURES

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care[1]. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the practitioner in light of all the circumstances presented. Thus, an approach that differs from the guidance in this document, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in this document when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to the guidance in this document will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of this document is to assist practitioners in achieving this objective.

[1] Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing, ___ N.W.2d ___ (Iowa 2013) Iowa Supreme Court refuses to find that the *ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures* (Revised 2008) sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, Stanley v. McCarver, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.

I. INTRODUCTION

This practice parameter was revised collaboratively by the American College of Radiology (ACR), the Society of Interventional Radiology (SIR), and the Society for Pediatric Radiology (SPR).

Prudent and ethical medical practice requires close communication between the patient and the physician. If the patient is unable to provide consent, the patient's legal representative or, in the case of a minor, the patient's parent(s) or legal guardian, represents the patient in the consent process. The patient or representative and, when appropriate, the patient's family must have every opportunity to understand the treatment or procedure the patient is to receive and its reasonable risks, benefits, and alternatives; to have all questions answered; and to fully consent to the treatment and procedure. The degree of disclosure required for a valid consent varies from state to state, but there are 2 generally recognized legal standards. The first is measured by what a reasonable physician in his or her professional judgment believes is appropriate to disclose to the patient. The degree of disclosure depends on perceptions of the physician in each case. The second legal standard is based on what a reasonable patient would want to know in the same or similar circumstances. It is important for each provider to understand his/her individual state requirements and exercise appropriate disclosure based on those standards.

Informed consent is a process of ongoing dialogue/discussion and is not the simple act of signing a formal document. Consent, even when granted by the patient in writing, may reasonably be withdrawn at any time; hence the need for ongoing dialogue. Consent must be documented in the medical record, and consent forms may serve to document the physician's discussion with the patient. These forms usually contain the patient's or representative's signature authenticating understanding of and consent to the treatments and procedures that will be performed. Another acceptable method of documentation is a physician note in the medical record indicating that the discussion took place and that the consent of the patient was obtained; however, this method is less defensible from a legal standpoint because it is only a one-party affirmation of that consent discussion. Informed consent with appropriate documentation must follow institutional policies and procedures and comply with applicable state law.

When obtaining informed consent, the consent process requires face-to-face discussion of the procedure between the physician or other qualified health care provider and the patient. The same standards apply to obtaining consent from the patient's health care representative or legally appointed guardian except that such consent may be reasonably obtained by telecommunication (see section V.B.7). In the case of a minor, consent should be obtained from the patient's parent(s) or guardian per institutional and/or state guidelines. The consent process should include discussion of the anticipated benefits and potential risks of the procedure, as well as reasonable alternatives to the procedure. The patient or representative should have the opportunity to ask questions and discuss the procedure, and all questions should be addressed. The physician performing the procedure has the final responsibility for assuring that all concerns and questions are addressed satisfactorily. Consent should not be obtained in a coercive manner.

II. INDICATIONS

Informed consent and appropriate documentation should be obtained for, but not limited to, the following procedures:

1. Invasive diagnostic or therapeutic procedures.
2. Moderate sedation. For further information, see the ACR–SIR Practice Parameter for Sedation/Analgesia [1].

Some minor procedures have a documented low incidence of adverse events (eg, intravenous injection of contrast media). These procedures may be exempted from the need for informed consent, but the decision not to obtain informed consent in these circumstances should be based on state law, institutional policy, departmental policy, and local community practice.

III. QUALIFICATIONS OF PERSONNEL

The physician or other health care provider who oversees or obtains informed consent should be familiar with the elements of informed consent, as well as all aspects of the procedure being proposed, the risks of the procedure, the expected benefits of the procedure, and reasonable alternatives to the proposed procedure.

IV. RESPONSIBILITIES OF PERSONNEL

In all cases requiring informed consent, the physician or health care provider performing the procedure or other qualified personnel assisting the physician should talk with the patient or representative, explain the procedure, answer all questions, and arrange for appropriate documentation of informed consent. This documentation might take the form of an executed consent form, videotape, or a note in the patient's medical record.

In institutions where department policy or legal advice based on state law requires informed consent for intravenous injections of contrast agents, ACR policy approves the obtaining of informed consent and injection of the contrast medium by qualified, credentialed technologists and nurses. For more information, see the ACR–SPR Practice Parameter for the Use of Intravascular Contrast Media [2].

V. SPECIFICATIONS AND DOCUMENTATION

Informed consent and appropriate documentation must be obtained prior to the initiation of any procedure that is likely to expose the patient to any significant risks and potential complications, except in emergency situations, as described in section V.C.

A. Radiation Exposure

When obtaining informed consent for image-guided procedures that may be associated with higher levels of radiation (see Appendix A), an explanation of the likelihood and characteristics of deterministic injury should be included in the consent discussion prior to the procedure [3-6]. Radiation dose may be determined and recorded in many different ways [7-9]. The ACR–AAPM Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures [10], the SIR–CIRSE Guidelines for patient radiation dose management, and the National Council on Radiation Protection & Measurements (NCRP) [5,6,11,12] indicate that when a cumulative air kerma at the reference point exceeds 5 Gy, special follow-up precautions should be instituted. Therefore, when a given procedure can be reasonably anticipated to approach this level (see Appendix A), a discussion of deterministic injury should occur as part of the consent process. Special consideration is required for the pregnant patient regarding fetal exposure (>100 mGy conceptus absorbed dose at early gestational stages) [13-15], and it should generate a discussion of potential effects of radiation exposure to the fetus as part of the consent process.

B. Protocol for Informed Consent for Elective Procedures

1. Before the proposed procedure is performed, the following will be explained to the patient or, if the patient is unable to provide consent, to the patient's legal representative:
   a. The purpose and nature of the procedure or treatment
   b. The method by which the procedure or treatment will be performed
   c. The risks, complications, and expected benefits or effects of such procedure or treatment
   d. The risk of not accepting the procedure or treatment
   e. Any reasonable alternatives to the procedure or treatment and their most likely risks and benefits
   f. The right to refuse the procedure or treatment

2. After the above items are explained and the physician or health care provider is satisfied that the patient understands the procedure and its possible consequences, the informed consent is executed and appropriately documented. This is most commonly done by having the patient sign a consent form.

3. The name of the person or his or her designee performing the procedure must appear on the consent form prior to the signature by the patient.

4. Documentation: A copy of the consent form(s) or videotape, if used, should be placed in the medical record. In all other situations a note should appear in the medical record that a discussion was held with the patient and that informed consent was obtained. The note should also include the date and time of the discussion, the content of the discussion, and an evaluation of the patient's understanding and response to information provided. A copy of any written informational materials given to the patient may also be included in the medical record.

5. Since the patient must be able to understand the risks at the time he or she gives consent, medications that affect the sensorium should be kept at a minimum and ideally not given to the patient <4 hours prior to the patient's giving consent. Chronic pain medications are less likely to affect the sensorium. No patient should be deprived of adequate pain control for the purpose of obtaining consent.

6. State statutes should be known and followed with regard to consent of those under legal age within that state. Some states have "emancipated minor" or "mature minor" statutes that may apply.

7. Telephone consent: If consent is sought from the patient's health care representative, legally appointed guardian, or family member who cannot be physically present to sign the consent form before the procedure, informed consent may be obtained by telephone. The discussion should be documented on the consent form with a note that the consent was obtained by telephone. In such cases it is advisable to have the discussion witnessed by a second hospital staff member who signs the form as a witness.

C. Protocol for Informed Consent for Emergency Procedures

This protocol defines the scope of the emergency exception to the informed consent requirement when a patient needs immediate medical care and is unable to give informed consent.

1. When a delay in treatment would jeopardize the health of a patient and the patient is unable to give informed consent, an exception to the requirement for obtaining informed consent from the patient is made.

2. If the patient is unable to consent and has a legally authorized representative who is available to consent, the treating physician must obtain the informed consent of the representative.

3. When informed consent cannot be obtained from the patient or from his or her legally authorized representative, the physician treating the patient should determine the immediacy of the need for treatment.
   a. A physician may provide any treatment or perform any procedure immediately required to prevent serious disability or death or to alleviate great pain and suffering.
   b. During the course of an operation or a procedure, a physician may perform any procedure that becomes necessary because of a condition discovered or arising during the operation or the procedure that presents an immediate threat to the life or the health of the patient.

4. The emergency exception to the requirement of informed consent does not extend to a conscious, competent adult patient, otherwise able to give his or her own informed consent, who has refused to consent to a treatment or a procedure.

5. The need for immediate treatment is documented in the patient's medical record. Documentation includes all information establishing the nature, immediacy, and magnitude of the problem and the impossibility of obtaining consent under the circumstances. Any consulting physicians should enter their findings and recommendations in the record. All notes should show the date and time that the determinations were made.

ACKNOWLEDGEMENTS

This practice parameter was revised according to the process described under the heading *The Process for Developing ACR Practice Parameters and Technical Standards* on the ACR website (http://www.acr.org/guidelines) by the Committee on Practice Parameters – Interventional and Cardiovascular Radiology of the ACR Commission on Interventional and Cardiovascular Radiology, the Committee on Practice Parameters – General, Small, and Rural Practice of the ACR Commission on General, Small, and Rural Practice, and the Committee on Practice Parameters – Pediatric Radiology of the ACR Commission on Pediatric Radiology, in collaboration with the SIR and the SPR.

Collaborative Committee – members represent their societies in the initial and final revisions of this practice parameter

ACR	SIR	SPR
Timothy L. Swan, MD, FACR, FSIR, Chair	Paul B. Shyn, MD	G. Peter Feola, MD
Lonnie J. Bargo, MD	Jon C. Davidson, MD	Manish N. Patel, DO
C. Matthew Hawkins, MD	Sanjeeva P. Kalva, MD	
Tammam N. Nehme, MD		
Richard B. Towbin, MD, FACR, FSIR		

Committee on Practice Parameters – Interventional and Cardiovascular Radiology
(ACR Committee responsible for sponsoring the draft through the process)

Aradhana M. Venkatesan, MD, FSIR, Chair
Clayton K.Trimmer, DO, FACR, Vice Chair
Drew M. Caplin, MD
Sean R. Dariushnia, MD
Jeremy L. Friese, MD, MBA
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Elizabeth A. Ignacio, MD
Sanjeeva P. Kalva, MD, FSIR
Minhajuddin S. Khaja, MD, MBA
Margaret Hsin-Shung Lee, MD
Susan K. O'Horo, MD, FSIR
Stephen P. Reis, MD
Wael Saad, MD, FSIR
Beth A. Schueler, PhD, FACR
Timothy L. Swan, MD, FACR, FSIR
Sanjit Tewari, MD
Joan C. Wojak, MD, FACR, FSIR

Committee on Practice Parameters – General, Small, and Rural Practices
(ACR Committee responsible for sponsoring the draft through the process)

Sayed Ali, MD, Chair
Marco A. Amendola, MD, FACR
Gory Ballester, MD
Lonnie J. Bargo, MD
Christopher M. Brennan, MD, PhD
Resmi A. Charalel, MD
Candice A. Johnstone, MD

Padmaja A. Jonnalagadda, MD
Pil S. Kang, MD
Jason B. Katzen, MD
Serena McClam Liebengood, MD
Gagandeep S. Mangat, MD
Tammam N. Nehme, MD

Committee on Practice Parameters – Pediatric Radiology
(ACR Committee responsible for sponsoring the draft through the process)

Beverley Newman, MB, BCh, BSc, FACR, Chair
Lorna P. Browne, MB, BCh
Timothy J. Carmody, MD, FACR
Brian D. Coley, MD, FACR
Lee K. Collins, MD
Monica S. Epelman, MD
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Sue C. Kaste, DO
Tal Laor, MD
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Sumit Pruthi, MBBS
Nancy K. Rollins, MD
Pallavi Sagar, MD

Philip S. Cook, MD, FACR, FSIR, Chair, Commission on Interventional and Cardiovascular Radiology
Lawrence A. Liebscher, MD, FACR, Chair, Commission on GSR
Robert S. Pyatt, Jr., MD, FACR, Vice Chair, Commission on GSR
Marta Hernanz-Schulman, MD, FACR, Chair, Commission on Pediatric Radiology
Jacqueline A. Bello, MD, FACR, Chair, Commission on Quality and Safety
Matthew S. Pollack, MD, FACR, Chair, Committee on Practice Parameters and Technical Standards

Comments Reconciliation Committee
Timothy L. Swan, MD, FACR, FSIR, Chair
Eric B. Friedberg, MD, FACR, Co-Chair
Sayed Ali, MD
Lonnie J. Bargo, MD
Jacqueline A. Bello, MD, FACR
Philip S. Cook, MD, FACR
Jon C. Davidson, MD
G. Peter Feola, MD
C. Matthew Hawkins, MD
Marta Hernanz-Schulman, MD, FACR
William T. Herrington, MD, FACR
Sanjeeva P. Kalva, MD
Lawrence A. Liebscher, MD, FACR
Tammam N. Nehme, MD
Beverley Newman, MB, BCh, BSc, FACR
Manish N. Patel, DO
Matthew S. Pollack, MD, FACR
Robert S. Pyatt, Jr., MD, FACR
Paul B. Shyn, MD
Richard B. Towbin, MD, FACR, FSIR
Clayton K. Trimmer, DO, FACR

Aradhana M. Venkatesan, MD, FSIR

REFERENCES

1. American College of Radiology. ACR-SIR practice parameter for sedation/analgesia. 2015; Available at: http://www.acr.org/~/media/F194CBB800AB43048B997A75938AB482.pdf. Accessed June 18, 2015.
2. American College of Radiology. ACR-SPR practice parameter for the use of intravascular contrast media. 2012; Available at: http://www.acr.org/~/media/536212D711524DA5A4532407082C89BA.pdf. Accessed June 18, 2015.
3. Miller DL, Balter S, Cole PE, et al. Radiation doses in interventional radiology procedures: the RAD-IR study: part II: skin dose. *J Vasc Interv Radiol.* 2003;14(8):977-990.
4. Miller DL, Balter S, Cole PE, et al. Radiation doses in interventional radiology procedures: the RAD-IR study: part I: overall measures of dose. *J Vasc Interv Radiol.* 2011;23(1):11-18.
5. National Council on Radiation Protection and Measurements. Radiation dose managmeent for fluoroscopically-guided interventional medical procedures. NCRP Report No. 168. Bethesda, MD; 2010.
6. National Council on Radiation Protection and Measurements. Outline of administrative policies for quality assurance and peer review of tissue reactions associated with fluoroscopically-guided interventions. NCRP Report No. 11. Bethesda, MD; 2014.
7. Miller DL, Balter S, Wagner LK, et al. Quality improvement guidelines for recording patient radiation dose in the medical record. *J Vasc Interv Radiol.* 2004;15(5):423-429.
8. American College of Radiology. ACR-AAPM technical standard for medical physics performance monitoring of image-guided radiation therapy (IGRT). 2014; Available at: http://www.acr.org/~/media/46A28AAB1C7D43C8B9311FCC0F6E1DA7.pdf. Accessed September 3, 2015.
9. American College of Radiology. ACR-ASTRO practice parameter for image-guided radiation therapy (IGRT). 2014; Available at: http://www.acr.org/~/media/69E10CCCA4784452B9FFA174529D0843.pdf. Accessed September 3, 2015.
10. American College of Radiology. ACR-AAPM technical standard for management of the use of radiation in fluoroscopic procedures. 2013; Available at: http://www.acr.org/~/media/F22C9D1FF46F43AAB001F9ED0466B7E9.pdf. Accessed June 18, 2015.
11. Kwon D, Little MP, Miller DL. Reference air kerma and kerma-area product as estimators of peak skin dose for fluoroscopically guided interventions. *Med Phys.* 2011;38(7):4196-4204.
12. Stecker MS, Balter S, Towbin RB, et al. Guidelines for patient radiation dose management. *J Vasc Interv Radiol.* 2009;20(7 Suppl):S263-273.
13. Brent RL. Saving lives and changing family histories: appropriate counseling of pregnant women and men and women of reproductive age, concerning the risk of diagnostic radiation exposures during and before pregnancy. *Am J Obstet Gynecol.* 2009;200(1):4-24.
14. Dauer LT, Thornton RH, Miller DL, et al. Radiation management for interventions using fluoroscopic or computed tomographic guidance during pregnancy: a joint guideline of the Society of Interventional Radiology and the Cardiovascular and Interventional Radiological Society of Europe with Endorsement by the Canadian Interventional Radiology Association. *J Vasc Interv Radiol.* 2012;23(1):19-32.
15. American College of Radiology. ACR-SPR practice parameter for imaging pregnant or potentially pregnant adolescents and women with ionizing radiation. 2013; Available at: http://www.acr.org/~/media/9E2ED55531FC4B4FA53EF3B6D3B25DF8.pdf. Accessed September 2, 2015.
16. Balter S, Miller DL, Vano E, et al. A pilot study exploring the possibility of establishing guidance levels in x-ray directed interventional procedures. *Med Phys.* 2008;35(2):673-680.

APPENDIX A

Procedures that have been associated with substantial radiation dose (Adapted from references [3,4,16])

- Transjugular intrahepatic portosystemic shunt creation
- Embolization (any location, any lesion)
- Stroke therapy
- Biliary drainage
- Visceral angioplasty and/or stent placement
- Stent-graft placement
- Chemoembolization
- Angiography and intervention for gastrointestinal hemorrhage
- Carotid stent placement
- Vertebroplasty
- Radiofrequency cardiac ablation
- Complex placement of cardiac electrophysiology devices
- Percutaneous coronary intervention

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*Practice parameters and technical standards are published annually with an effective date of October 1 in the year in which amended, revised or approved by the ACR Council. For practice parameters and technical standards published before 1999, the effective date was January 1 following the year in which the practice parameter or technical standard was amended, revised, or approved by the ACR Council.

Development Chronology for this Practice Parameter
2001 (Resolution 49)
Revised 2006 (Resolution 32)
Amended 2007 (Resolution 38)
Revised 2011 (Resolution 39)
Amended 2014 (Resolution 39)
Revised 2016 (Resolution 17)

EXHIBIT 2

UNITED STATES DISTRICT COURT

DISTRICT OF ARIZONA

IN RE BARD IVC FILTERS PRODUCTS LIABILITY LITIGATION	) No. MD-15-02641-PHX-DGC

DO NOT DISCLOSE - SUBJECT TO FURTHER CONFIDENTIALITY REVIEW

VIDEOTAPED DEPOSITION OF DONNA-BEA TILLMAN, Ph.D.

WASHINGTON, D.C.

FRIDAY, AUGUST 4, 2017

9:18 A.M.

Reported by: Leslie A. Todd

Q Would you agree with me that -- that the risk-benefit analysis for purposes of using a medical device like a Bard filter should be something that physicians should have the ability to do in order to provide informed consent to their patients?

A So at the risk of rephrasing your question, I think that physicians need to have enough information to understand the risks and the benefits in order to advise their patients.

Q And to advise their patients pursuant to a physician's obligation to provide informed consent. Agreed?

A And to provide informed consent.

Q What does "fair and balanced" mean as a regulatory term?

A Well, I would interpret it to mean that you present data that's both favorable and not favorable when you're trying to make a scientific argument.

Q What are -- there's an issue here about monitoring, right, whether or not the labeling should have included monitoring. I think you comment on it. Dr. Kessler comments on it.

EXHIBIT 3

The NEW ENGLAND JOURNAL of MEDICINE

Perspective

JUNE 1, 2006

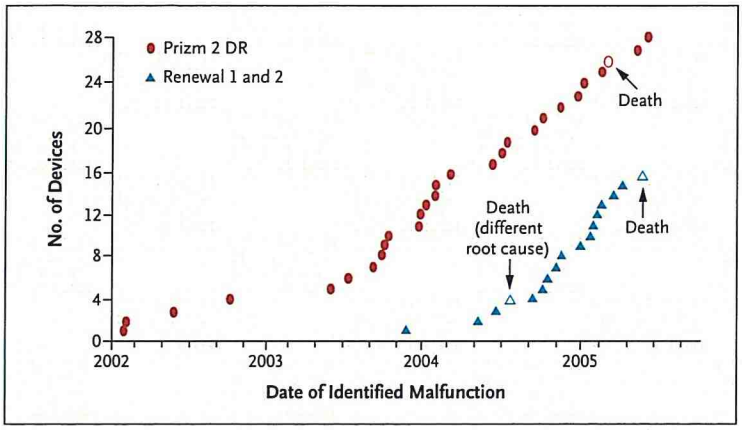
Life-Threatening Malfunction of Implantable Cardiac Devices

Robert J. Myerburg, M.D., David W. Feigal, Jr., M.D., M.P.H., and Bruce D. Lindsay, M.D.

During the summer of 2005, in the wake of widespread criticism of its failure to communicate the potentially fatal malfunctions of its implantable defibrillators,[1,2] Guidant Corporation created an independent panel, of which we were members. The purpose of the panel was to conduct an unbiased examination of these incidents, including the methods used to identify the malfunctions and evaluate products in the postmarketing phase and the policies regarding communication within the corporation and with physicians and patients. The panel was also asked to recommend corrective actions. Concurrently, the Heart Rhythm Society — which represents physicians who implant cardiac devices — established a task force to examine assessments of device performance and develop policy recommendations and guidelines.[3] Since the report by the independent panel had implications for the device industry in general, Guidant made it available to the public.[4]

Three points quickly emerged as guidelines for the panel's deliberations. First, manufactured products can never be entirely free of design or manufacturing flaws, but when the consequence of a malfunction is a potentially fatal event, tolerance and surveillance strategies should aim to achieve a risk of malfunction that is as close to zero as possible. Second, physicians must know about the performance features of any device they recommend for a patient, so that they can carry out their ethical obligation of obtaining informed consent. This information must be in a form that is understandable and clinically useful. And third, patients have a right to obtain product information so that they can make informed decisions about risks and benefits and can understand what expectations are reasonable.

The panel recognized that, as compared with the clinical benefit of implantable cardiac devices, the rate of serious malfunctions is very low. We also concluded, however, that if a malfunction is life-threatening, even a low risk of its occurrence takes on importance beyond its numbers. Although it is intuitively clear that any manufactured product will have a measurable failure rate, until recently, industry had not provided information to physicians about potentially serious malfunctions when the failure rates fell within the overall performance predic-



Defects Leading to Potential Failure in Two Types of Guidant Implantable Defibrillators.

The numbers of implantable defibrillators identified between 2002 and mid-2005 as having defects that predisposed them to short-circuiting (arcing), with an attendant risk of failure to deliver therapy when needed, are shown. The Prizm 2 DR was a conventional implantable defibrillator, and Renewal 1 and 2 were implantable defibrillators with biventricular pacing capability. Open symbols represent malfunctions that were associated with the death of a patient; one of these malfunctions was due to a random manufacturing defect rather than to the identified defect that resulted in short-circuiting ("different root cause"). Adapted from Myerburg et al.[4]

tions.[4] In most cases, these malfunctions were simply folded into overall statistics that also included less critical malfunctions and the expected depletion of batteries over time — a practice that made serious but infrequent malfunctions invisible to physicians and patients.

Although there is no industry-wide performance standard for malfunction rates in the cardiac-device industry, all companies are required by the Food and Drug Administration (FDA) to evaluate device malfunctions systematically in the post-marketing phase, to identify those that are clinically significant, to correct defects, and to act to prevent failures in performance. These internal processes necessarily center on engineering skills and methods. But the consequences of device malfunctions are more than an issue for engineering: they have clinical implications for patients that may include a risk of fatal events. Thus, engineering performance standards are insufficient benchmarks without evaluation by experts of the possible effects on individual patients. The independent panel concluded that the lack of adequate clinical expertise, combined with undue reliance on arbitrary statistical criteria, led to decisions that had potentially and manifestly serious consequences. The graph shows the number of implantable defibrillators that were identified as having defects that predisposed them to short-circuiting (arcing) between 2002 and 2005.

As the number of defibrillators with life-threatening malfunctions continued to grow, the overall reliability of the products remained within the predicted rates. Therefore, in keeping with the company's standard practices at the time, the engineering group at Guidant decided, without any input from physicians, that it was unnecessary to inform physician-customers about these events.[4] In addition, implantations of the potentially defective defibrillators continued for a time, and physicians, hospitals, and patients were not informed that the devices had flaws that could result in the inability to deliver therapy when necessary. It seems clear that the industry needs physicians with defined responsibilities focused on patient safety to provide recommendations to corporate leaders.

Post-marketing surveillance continues to be a challenge for the FDA and industry. Clinical trials rarely identify significant signals of very uncommon adverse events, and only a small proportion of later events are ever reported. One potential solution to this limitation of tracking, at least for cardiac devices, lies in the National Cardiovascular Data Registry mandated by the Centers for Medicare and Medicaid services for implantable cardioverter–defibrillators, which could be expanded and adapted to other databases. Moreover, the number of malfunctions that occur at the time of deaths that are assumed to be from natural causes remains unknown, because most devices are not returned to manufacturers for evaluation after patients die.

The FDA recently announced plans to address post-marketing surveillance more actively, including having electrophysiology experts from its Circulatory System Devices Panel review the post-marketing performance of implantable devices. The Heart Rhythm Society's task force also suggested that the FDA establish post-marketing advisory committees to recommend actions that should be taken when malfunctions are identified in defibrillators or pacemakers.[5] These steps could help the FDA address many issues, in-

cluding the lack of standard definitions and classifications of malfunctions that makes evaluating reports from different manufacturers problematic. It is uncertain whether the FDA could appreciably enhance the effectiveness of its post-marketing surveillance program without expanding both its authority and its budget. But if patient safety is a priority, the federal government should appropriate the funds required to make this effort feasible, without adversely influencing the FDA's other areas of responsibility.

In the meantime, companies must reevaluate their approach to patient safety in the context of communication. A critical question is when and how information about product performance should be communicated to physicians and patients. Although the issues — both ethical and practical — are complex, one conclusion is clear: transparency in matters that affect patient safety should be embraced as a primary corporate obligation.

In the past, this industry has not had a good record of open communication, but transparency does benefit companies that want to be viewed as trusted partners in the health care enterprise. As the panel noted, transparency may be passive, with information made available to those who seek it; active, with information targeted to specific groups of stakeholders; or forced, with a third party bringing forth information that elicits further disclosure by a company, as a defensive move. From the perspective of physicians' and patients' expectations, corporate responsibility, and public perception, we believe that proactive communication policies, centering on the proper use of active and passive transparency, should be the norm. Insofar as such communication is hindered by perceived business conflicts, the solution may lie in new regulatory definitions that distinguish informational actions from those that indicate the removal of a device. Changing language can be difficult, since much of it is embedded in statutory requirements.

The panel also recommended that Guidant establish an independent review group to provide unbiased analysis of information on product performance and advice on decisions about external communications. Voluntary, independent review at the level suggested is a notion both foreign and frightening to most corporations, whose perceived need is to protect business interests. But corporate culture fosters a loyalty to corporate goals that may create unintended bias and distorted perceptions about product performance and patient safety. Independent review groups could assist corporations by generating unbiased advice that was responsive to society's view of the best business practices and clinical priorities.

Historically, corporations have — by themselves — set the expectations for device reliability and the communication of product malfunctions, seeking little input from patients, physicians, or professional organizations. This practice developed in the early years of the industry, when the combination of small numbers of device recipients and low malfunction rates made it difficult to detect problems. With the explosive growth of the industry in recent years, previously unrecognizable signals have become increasingly visible. Clearly, strategies for evaluating and communicating device malfunctions must be adjusted accordingly. Our conclusion is that industry should work collaboratively with physicians, professional societies, patient representatives, and regulatory agencies to establish reasonable standards and guidelines for the device industry to follow. Patients deserve nothing less.

The opinions expressed in this article reflect the views of the authors and are not endorsed by Guidant or any of the institutions or organizations with which the authors are affiliated.

Drs. Myerburg, Feigal, and Lindsay report having received honoraria from Guidant. Dr. Myerburg also reports having received consulting fees from Procter & Gamble and Reliant and having served as an expert witness. Dr. Lindsay reports having received consulting fees from Medtronic.

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Dr. Myerburg is a professor of medicine and physiology at the University of Miami Miller School of Medicine, Miami. Dr. Feigal is a partner at NDA Partners, Phoenix, Ariz., and the former director of the Center for Devices and Radiological Health, Food and Drug Administration, Rockville, Md. Dr. Lindsay is an associate professor of medicine and director of cardiac electrophysiology at Washington University School of Medicine, St. Louis.

1. Meier B. Maker of heart device kept flaw from doctors. New York Times. May 24, 2005:A1.
2. Steinbrook R. The controversy over Guidant's implantable defibrillators. N Engl J Med 2005;353:221-4.
3. Proceedings Document from the Policy Conference on Pacemaker and ICD Performance. Presented by the Heart Rhythm Society and the Food and Drug Administration, September 16, 2005. (Accessed May 11, 2006, at http://www.hrsonline.org/advocacyDocs/HRS-device_conference.pdf.)
4. Myerburg RJ, Apostolakis GE, Beller GA, et al. Report of the Independent Panel of Guidant Corporation. March 20, 2006. (Accessed May 11, 2006, at http://www.guidant.com/panel/panel.pdf.)
5. Heart Rhythm Society Task Force report on device performance policies and guidelines. Heart Rhythm (in press).

EXHIBIT 4

Evidence-Based Evaluation of Inferior Vena Cava Filter Complications Based on Filter Type

Steven E. Deso, MD[1] Ibrahim A. Idakoji, MD, MPH[1] William T. Kuo, MD[1]

[1] Division of Vascular and Interventional Radiology, Stanford University Medical Center, Stanford, California

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Address for correspondence Steven E. Deso, MD, Division of Vascular and Interventional Radiology, Stanford University Medical Center, 300 Pasteur Drive, H-3651, Stanford, CA 94305 (e-mail: sdeso@stanford.edu).

Abstract

Many inferior vena cava (IVC) filter types, along with their specific risks and complications, are not recognized. The purpose of this study was to evaluate the various FDA-approved IVC filter types to determine device-specific risks, as a way to help identify patients who may benefit from ongoing follow-up versus prompt filter retrieval. An evidence-based electronic search (FDA Premarket Notification, MEDLINE, FDA MAUDE) was performed to identify all IVC filter types and device-specific complications from 1980 to 2014. Twenty-three IVC filter types (14 retrievable, 9 permanent) were identified. The devices were categorized as follows: conical ($n = 14$), conical with umbrella ($n = 1$), conical with cylindrical element ($n = 2$), biconical with cylindrical element ($n = 2$), helical ($n = 1$), spiral ($n = 1$), and complex ($n = 1$). Purely conical filters were associated with the highest reported risks of penetration (90–100%). Filters with cylindrical or umbrella elements were associated with the highest reported risk of IVC thrombosis (30–50%). Conical Bard filters were associated with the highest reported risks of fracture (40%). The various FDA-approved IVC filter types were evaluated for device-specific complications based on best current evidence. This information can be used to guide and optimize clinical management in patients with indwelling IVC filters.

Keywords

- IVC filters
- nonthrombotic complications
- interventional radiology

CME Objective: Upon completion of this article, the reader should be able to distinguish the various retrievable and permanent IVC filter designs, and explain the most common complications associated with the various designs.

Accreditation: This activity has been planned and implemented in accordance with the Essential Areas and Policies of the Accreditation Council for Continuing Medical Education (ACCME) through the joint providership of Tufts University School of Medicine (TUSM) and Thieme Medical Publishers, New York. TUSM is accredited by the ACCME to provide continuing medical education for physicians.

Credit: Tufts University School of Medicine designates this journal-based CME activity for a maximum of ***1 AMA PRA Category 1 Credit™***. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

The use of inferior vena cava (IVC) filters has dramatically increased over the past three decades in the United States, and the number of filter insertions doubled between 1998 and 2008.[1,2] By 2012, an estimated 259,000 IVC filters were placed in the United States alone,[3] coinciding with a growing number of Food and Drug Administration (FDA)-approved devices. Consequently, the increasing variety of filters along with rising overall use has resulted in increased complications from indwelling IVC filters; this prompted the FDA to issue a safety alert urging all physicians caring for patients with indwelling filters to consider removing the filter as soon as protection from pulmonary embolism (PE) is no longer needed.[4] Despite this recommendation, many devices are not adequately followed for removal, and the large number of filter types now encountered on routine imaging has made proper device identification difficult. The purpose of this study was to evaluate the various FDA-approved IVC filter designs to determine device-specific risks, as a way of

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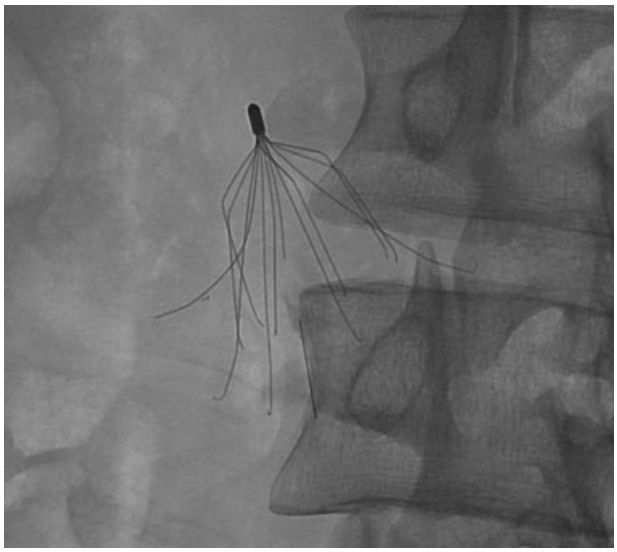

Fig. 1 Fluoroscopic image showing a G2 filter with multiple fractured components.

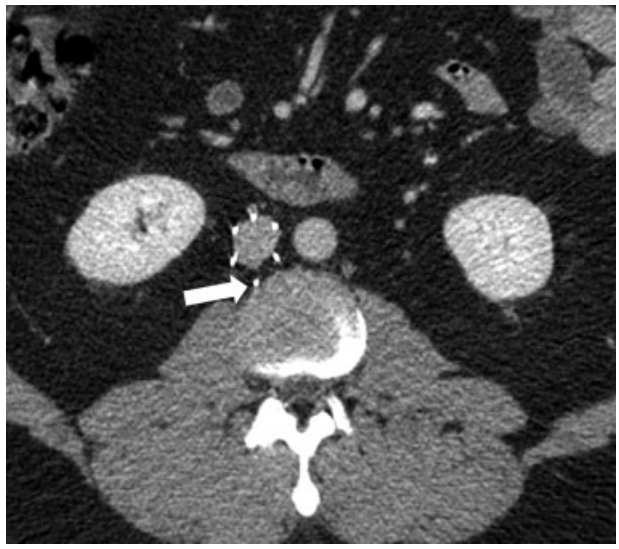

Fig. 3 Axial CT image showing a 12F Stainless Steel Greenfield filter in place complicated by component perforation (arrow).

helping to identify patients who may benefit from ongoing follow-up or prompt filter retrieval.

Materials and Methods

Identification of IVC Filter Types

The FDA Premarket Notification Database[5] was searched electronically to identify all IVC filters receiving 510(k) clearance (product code DTK—filter, intravascular, cardiovascular) between 1980 and 2014.

Classification of Filter Complications

IVC filter complications were classified according to the Society of Interventional Radiology (SIR) guidelines[6] as follows:

Fracture: Breakage or separation of any filter component due to structural failure.[6] The fractured components can remain in situ or undergo distal embolization (►**Fig. 1**).

Insertional problems: Malfunctions in filter deployment including tilting of the filter more than 15 degrees from the IVC axis, incomplete opening, and prolapse of filter components[6] (►**Fig. 2**).

IVC perforation: Visualization of one or more filter components extending greater than 3 mm beyond the caval wall or into an adjacent structure[6] such as the duodenum, aorta, psoas muscle, kidney, or vertebral body. Grading schemes defining the degree of perforation have been described in the literature[7] (►**Fig. 3**).

Migration: Movement of an IVC filter greater than 2 cm along the IVC beyond the initial placement position.[6] Filter migration may result in filter embolization into the right atrium, right ventricle, or pulmonary arteries (►**Fig. 4**).

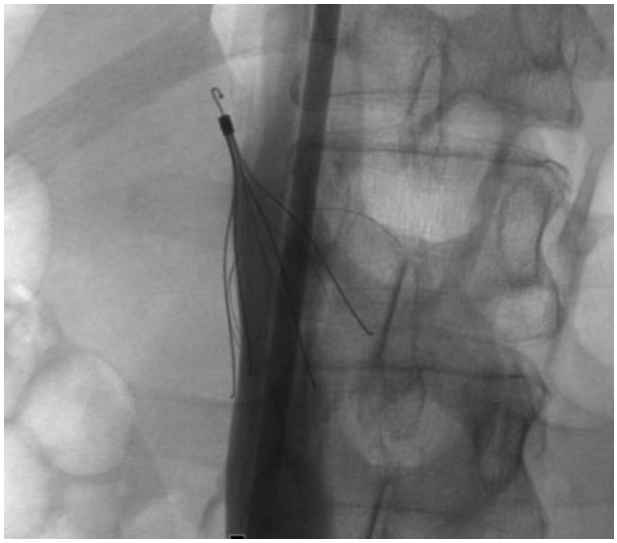

Fig. 2 Fluoroscopic images showing a severely tilted and tip embedded Celect filter.

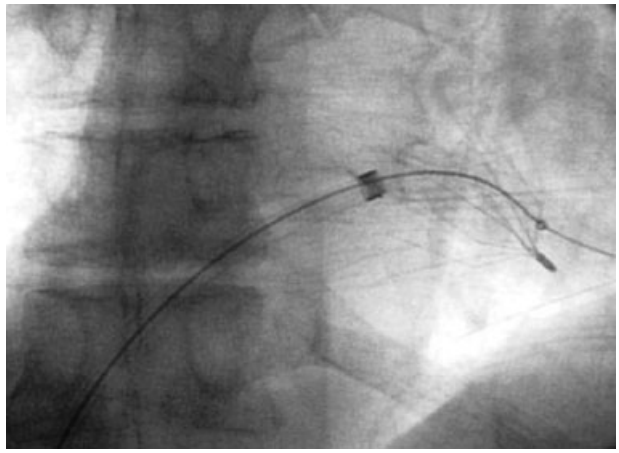

Fig. 4 Fluoroscopic image demonstrating an IVC filter that has migrated into the right ventricle.

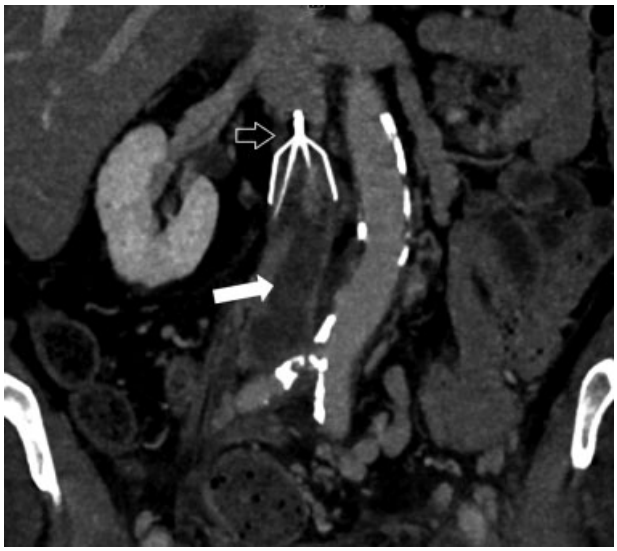

Fig. 5 Coronal CT image showing a Bard filter (open arrow) in place with acute thrombotic occlusion of the IVC (solid arrow).

IVC occlusion: Acute or chronic thrombotic occlusion of the IVC following filter placement[6] (►**Fig. 5**).

Evidence-Based Search of Filter Complications

An electronic MEDLINE search was performed using the following index search terms: "IVC filter" OR "inferior vena cava filter" OR "ALN filter" OR "Bard Eclipse" OR "Bard G2" OR "Bard G2X" OR "Bard Recovery" OR "Bard Denali" OR "Bard Meridian" OR "Simon Nitinol" OR "Vena Tech LGM" OR "Vena Tech LP" OR "Greenfield filter" OR "Bird's Nest filter" OR "Celect filter" OR " Günther Tulip" OR "Optease" OR "Trapease" OR "Safeflo" OR "Option filter" OR "Crux vena cava filter." The results were filtered for English language, clinical trial study type, human species, and date range from 1980 to 2014 (►**Fig. 6**). All potentially relevant articles were collected for analysis. The references within these articles were reviewed to obtain additional relevant articles for analysis. A data extraction form was used to record the following information: filter type, retrieval rate, complications, and frequency of complications per filter type. Two reviewers verified the accuracy of all data prior to analysis. The FDA Manufacturer and User Facility Device Experience (MAUDE) database[8] was queried electronically (1992–2014) to identify additional adverse events associated with IVC filter use (product class —filter, intravascular, cardiovascular).

Results

Twenty-four IVC filters were identified. From this group, the Edwards Mobin-Uddin device was excluded as it was removed from the market in 1986.[9] From the remaining group, nine filters cleared for permanent use, and 14 filters cleared for retrievable or permanent use, were identified (►**Table 1**). The device distribution based on geometry was as follows: conical ($n = 15$), conical with umbrella ($n = 1$), conical with cylindrical element ($n = 2$), biconical with cylindrical

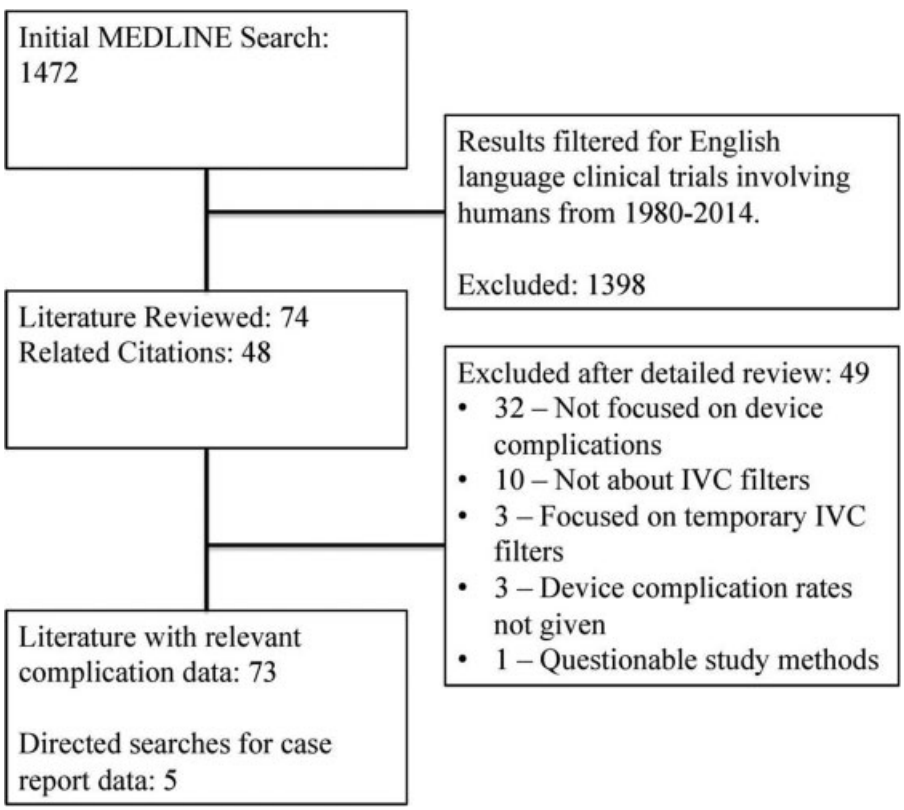

Fig. 6 Literature screening flowchart.

Table 1 IVC Filters in the United States (1980–2014)

Permanent filters	Retrievable filters[a]
• 24F stainless steel Greenfield (Boston Scientific, Natick, MA)[b] • 12F stainless steel Greenfield (Boston Scientific) • Titanium Greenfield (Boston Scientific) • Vena Tech LGM (B. Braun Medical, Bethlehem, PA)[b] • Vena Tech LP (B. Braun Medical) • Trapease (Cordis Endovascular, Warren, NJ) • Bird's Nest (Cook, Bloomington, IN) • Simon Nitinol (Bard Peripheral Vascular, Tempe, AZ) • SafeFlo (Rafael Medical Technologies, Dover, DE)[b]	• ALN (ALN International, Miami, FL) • Recovery (Bard Peripheral Vascular)[b] • G2 (Bard Peripheral Vascular)[b] • G2X (Bard Peripheral Vascular)[b] • Eclipse (Bard Peripheral Vascular)[b] • Meridian (Bard Peripheral Vascular)[b] • Denali (Bard Peripheral Vascular) • Günther Tulip (Cook) • Celect (Cook)[b] • Celect Platinum (Cook) • Optease (Cordis Endovascular, Warren, NJ) • Option (Argon, Plano, TX)[b] • Option Elite (Argon, Plano, TX) • Crux (Volcano, San Diego, CA)

[a]All retrievable filters are also approved for permanent use.
[b]No longer manufactured but may still be encountered from prior implantation.

element ($n = 2$), helical ($n = 1$), spiral with umbrella ($n = 1$), and complex ($n = 1$) (►**Fig. 7**).

Reported device-specific complications were identified among all filter types, and the highest reported complications for each device are summarized in ►**Table 2**. The risk of complications was found to vary widely depending on the specific IVC filter type.

Fracture

Early conical Bard Peripheral Vascular (Tempe, AZ) filters were associated with the highest reported rates of fracture. The fracture rate for the original Bard Recovery device was 5.5 to 25% with an estimated incidence of 39.5% at 65.7 months.[10–14] The fracture rate for the Bard G2 devices (G2, G2X, Eclipse, Meridian) was initially 1.2 to 12%, but the highest reported rate was later found to be 38% at 60 months.[11,13,15,16] High fracture rates were also reported for the Simon Nitinol filter (Bard) (10–16%)[17,18] and the Optease/Trapease (Cordis, Miami Lakes, FL) (up to 50%).[19]

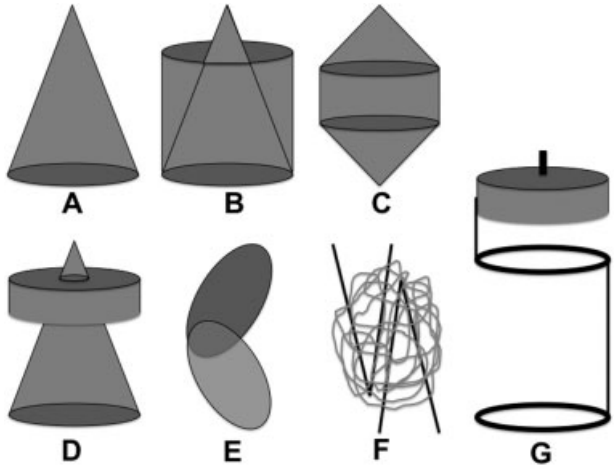

Fig. 7 IVC filter geometries: (**A**) conical, (**B**) conical with cylindrical element, (**C**) biconical with cylindrical element, (**D**) conical with umbrella, (**E**) helical, (**F**) complex, (**G**) spiral with umbrella.

Insertional Issues

Filter tilting greater than 15 degrees during insertion were reported among the following conical filters: Bard Recovery (2.3–15%),[20,21] Bard G2/G2X/Eclipse (14–18%),[15,22,23] Cook (Bloomington, IN) Günther Tulip (11.5–24%),[24–27] 24F Greenfield (Boston Scientific, Marlborough, MA) (7–12%),[28,29] 12F Stainless Steel Greenfield (Boston Scientific) (9.9–55%),[30,31] and Titanium Greenfield (Boston Scientific) (8.3–41%).[30,32,33] In addition, wire prolapse up to 70% was reported for the Cook Bird's Nest filter.[34]

Inferior Vena Cava Perforation

Purely conical filters were associated with the highest reported rates of IVC perforation and were reported as follows: Bard Recovery (27–100%),[12,14] Bard G2/G2X/Eclipse (26–44%),[15,23] Bard Simon Nitinol (25–95%),[17,18] Cook Günther Tulip (22–78%),[7,35–37] Cook Celect (22–93%),[7,35,38,39] and Titanium Greenfield (prior to hook modification) (13–50%).[40,41] In addition, IVC strut perforation up to 85% was reported for the Cook Bird's Nest filter.[34]

Migration

Migration rates greater or equal to 10% were reported among the following devices: Bard Recovery (0–10%),[10,12,20] Bard G2 (12–25%),[15,20] Titanium Greenfield (7.5–15%),[33,42] Cook Günther Tulip (2.4–12.5%),[26,36,43] and Vena Tech LGM (6–18.4%).[33,44,45]

Inferior Vena Cava Occlusion

Filters with a cylindrical component (Vena Tech LGM, Trapease/Optease) or umbrella element (Simon-Nitinol) were associated with high rates of caval thrombosis. The highest reported rate of IVC occlusion for the Trapease/Optease filters was 28.6%.[46] The rates of chronic IVC occlusion with the Simon Nitinol filter range from 3.5 to 50%,[17,47–49] and for the VenaTech LGM, the IVC occlusion rate is as high as 65% at 9 years.[45]

Table 2 Highest reported radiographically identifiable complications for each filter type

Device (year FDA cleared)	Fracture	IVC perforation	Migration	IVC occlusion
ALN (2008)	Case reports (0%)[54–56]	3.4% (3.4%)[54]	3% (1.4–3%)[57,58]	Case reports (0%)[54,58,59]
Recovery (2003/2005[a])	39.5% at 65.7 mo 25% (5.5–25%)[10–14]	100% (27–100%)[12,14]	10% (0–10%)[10,12,20,21]	Case reports (0%)[14]
G2 (2005/2008[a]) G2X (2008) Eclipse (2008) Meridian (2011)	38% at 60 mo 12% (1.2–12%)[11,13,15,16,23,60]	44% (18–44%)[15,23,60,61]	25% (12–25%)[15,20,23]	2.2% (0–2.2%)[22,60]
Denali (2013)	Case reports[62]	2.5% (2.5%)[63]	Limited data	Limited data
Simon Nitinol (1990)	16% (10–16%)[17,18]	95% (25–95%)[17,18]	5% (0–5%)[18,47]	50% (3.5–50%)[17,47–49]
LGM/Vena Tech LGM (1989)	Case reports[64]	Case reports (0%)[44,65]	18.4% (6–18.4%)[33,44,45,66]	65% at 9 y (3.7%/y)[45]
Vena Tech LP (2001)	Limited data	Case reports (0%)[67]	Case reports (0%)[67]	Limited data
24F SS Greenfield (1973)	Case reports[68]	15% (2–15%)[69,70]	2% (2%)[69]	5% (2–5%)[28,29,71,72]
12F SS Greenfield (1995)	0.3% (0.3%)[73]	1% (1%)[73]	2.6% (2.6%)[73]	12% (5–12%)[31,74]
Titanium Greenfield (1989)	3.8% (3.8%)[74]	50% (13–50% prior to hook modification, 1% with MH design)[40,41]	15% (7.5–15%)[33,42]	20% (3.5–20%)[32,75]
Günther Tulip (2000/2003[a])	0.3% (0.3%)[36]	78% (22–78%)[7,35–37]	12.5% (2.4–12.5%)[26,36,43]	4.1% (2.4–4.1%)[36,43]
Celect (2007/2008[a]) Celect Platinum (2012)	5.6% (4.3–5.6%)[39,76]	93% (22–93%)[7,35,38,39]	4.3% (0–4.3%)[38,76,77]	2.5% (2.5%)[38]
Bird's Nest (1989)	4% (3–4%)[41]	85% (85%)[34]	1.1% (1.1%)[78]	4.7% (2.9–4.7%)[34,78]
Optease (2002/2004[a]) Trapease (2000)	50% (0–50%)[19,79-84]	Case Reports (0%)[79,83,84]	0.9% (0–0.9%)[79–81,83,84]	29% (0.8–29%)[46,79,83-86]
Option (2009)	Limited data	10% (2.9–10%)[37,87]	2% (2%)[87]	4% (4%)[87]
Crux (2012)	Limited data (0%)[88]	Limited data	Limited data (0%)[88]	Limited data (7.2% nonocclusive IVC thrombus)[88]

Abbreviations: FDA, Federal Drug Administration; IVC, inferior vena cava.
Note: For the SafeFlo filter (2009), no significant clinical data are available, and the device is no longer manufactured.
[a]Subsequent year when filter was cleared for retrieval indication.

Discussion

Over the past few decades, IVC filter use has risen in the United States,[1,2] which has led to increased recognition of a wide range of potential filter-related complications. These complications include fracture, IVC perforation, component embolization, device migration, and IVC occlusion. In response to rising complication rates, the current FDA Safety Alert on IVC filters recommends filter removal when protection from PE is no longer needed. More recently, the FDA released an additional Safety Communication stating that the risk-to-benefit ratio begins to favor IVC filter removal within 29 to 54 days after implantation, if the risk of PE has passed.[50,51]

The systematic review by Angel et al[52] concluded that filter complications are a serious concern associated with long-term filter use, but the study did not address device-specific risks, and there was no analysis specifically of complications from permanent IVC filters. A large variety of retrievable and permanent IVC filters are commonly encountered on routine imaging studies, but the myriad number of filter types and their associated complications prevents interpretation of such radiographic findings. Filter-related complications may therefore go unrecognized or underappreciated as potential causes of morbidity in patients, including those presenting with intractable abdominal pain from filter penetration.[53]

The goal of this study was to evaluate the various FDA-approved IVC filter designs to determine device-specific risks, and to help identify patients who may benefit from ongoing follow-up versus prompt filter retrieval. First, we identified the 23 filter types currently encountered in the United States. Next, the complications associated with each filter type were identified. Although we initially searched the FDA MAUDE database, we soon realized these data were based on voluntary reporting and there was gross underreporting of complications. Therefore, we chose to use evidence-based methods to identify the highest reported complication rates in the literature for each filter type (►**Table 2**).

These data revealed a high risk of fracture among Bard and Cordis (Miami Lakes, FL) IVC filters, including a fracture incidence of 39.5% at 65.7 months with the Bard Recovery device,[10–14] a 38% risk of fracture at 60 months among the Bard G2 type filters,[11,13,15,16] and a 50% risk of fracture with Cordis Optease/Trapease devices.[19] A high risk of IVC perforation was reported with the Bard Recovery and Cook Celect filters, with penetration rates exceeding 90% for both.[7,12] For permanent filter types, a high risk of IVC occlusion was reported among the Simon Nitinol and Vena Tech LGM,[9] filters with occlusion rates of 50 and 65% (at 9 years),[45,49] respectively. Overall, as these complications appear to be related to filter geometry, one should always assess for IVC perforation, when a conical device is identified, and IVC occlusion, when a cylindrical or umbrella filter component is identified.

This study is limited by the quality of available data on IVC filters, and some filter types in this study were limited published data. In addition, many studies had limited long-term follow-up; therefore, it is possible that the true risk of complications for these filter types could be even higher than currently reported, as complications tend to increase after longer dwell times. Nevertheless, mitigation against these effects was attempted by identifying the highest complication rates reported so far in the literature. Future studies should involve methods to provide constant updating of filter complication rates as new data emerge in larger cohorts.

References

1 Duszak R Jr, Parker L, Levin DC, Rao VM. Placement and removal of inferior vena cava filters: national trends in the Medicare population. J Am Coll Radiol 2011;8(7):483–489
2 Stein PD, Kayali F, Olson RE. Twenty-one-year trends in the use of inferior vena cava filters. Arch Intern Med 2004;164(14): 1541–1545
3 Smouse BJ. Is market growth of vena cava filters justified? Endovasc Today 2010:74–77
4 Food and Drug Administration. Removing Retrievable Inferior Vena Cava Filters: Initial Communication. Published August 9, 2010. Available at: http://www.fda.gov/MedicalDevices/Safety/AlertsandNotices/ucm221676.htm. Accessed July 30, 2015
5 Food and Drug Administration. 510(K) Premarket Notification Database. Published 2014. Available at: http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfpmn/pmn.cfm. Accessed January 1, 2015
6 Caplin DM, Nikolic B, Kalva SP, Ganguli S, Saad WE, Zuckerman DA; Society of Interventional Radiology Standards of Practice Committee. Quality improvement guidelines for the performance of inferior vena cava filter placement for the prevention of pulmonary embolism. J Vasc Interv Radiol 2011;22(11):1499–1506
7 Durack JC, Westphalen AC, Kekulawela S, et al. Perforation of the IVC: rule rather than exception after longer indwelling times for the Günther Tulip and Celect retrievable filters. Cardiovasc Intervent Radiol 2012;35(2):299–308
8 Food and Drug Administration. MAUDE - Manufacturer and User Facility Device Experience Database. Published 2014. Available at: http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfmaude/search.cfm. Accessed January 1, 2015
9 Bakal CW, Silberzweig JE. Vascular and Interventional Radiology: Principles and Practice. New York, NY: Thieme; 2011
10 Tam MD, Spain J, Lieber M, Geisinger M, Sands MJ, Wang W. Fracture and distant migration of the Bard Recovery filter: a retrospective review of 363 implantations for potentially life-threatening complications. J Vasc Interv Radiol 2012;23(2): 199–205.e1
11 Nicholson W, Nicholson WJ, Tolerico P, et al. Prevalence of fracture and fragment embolization of Bard retrievable vena cava filters and clinical implications including cardiac perforation and tamponade. Arch Intern Med 2010;170(20):1827–1831
12 Hull JE, Robertson SW. Bard Recovery filter: evaluation and management of vena cava limb perforation, fracture, and migration. J Vasc Interv Radiol 2009;20(1):52–60
13 Vijay K, Hughes JA, Burdette AS, et al. Fractured Bard Recovery, G2, and G2 express inferior vena cava filters: incidence, clinical consequences, and outcomes of removal attempts. J Vasc Interv Radiol 2012;23(2):188–194
14 Kalva SP, Athanasoulis CA, Fan CM, et al. "Recovery" vena cava filter: experience in 96 patients. Cardiovasc Intervent Radiol 2006; 29(4):559–564
15 Binkert CA, Drooz AT, Caridi JG, et al. Technical success and safety of retrieval of the G2 filter in a prospective, multicenter study. J Vasc Interv Radiol 2009;20(11):1449–1453
16 An T, Moon E, Bullen J, et al. Prevalence and clinical consequences of fracture and fragment migration of the Bard G2 filter: imaging

and clinical follow-up in 684 implantations. J Vasc Interv Radiol 2014;25(6):941–948
17 Poletti PA, Becker CD, Prina L, et al. Long-term results of the Simon nitinol inferior vena cava filter. Eur Radiol 1998;8(2):289–294
18 McCowan TC, Ferris EJ, Carver DK, Molpus WM. Complications of the nitinol vena caval filter. J Vasc Interv Radiol 1992;3(2): 401–408
19 Sano M, Unno N, Yamamoto N, Tanaka H, Konno H. Frequent fracture of TrapEase inferior vena cava filters: a long-term follow-up assessment. Arch Intern Med 2012;172(2):189–191
20 Cantwell CP, Pennypacker J, Singh H, Scorza LB, Waybill PN, Lynch FC. Comparison of the recovery and G2 filter as retrievable inferior vena cava filters. J Vasc Interv Radiol 2009;20(9): 1193–1199
21 Binkert CA, Sasadeusz K, Stavropoulos SW. Retrievability of the recovery vena cava filter after dwell times longer than 180 days. J Vasc Interv Radiol 2006;17(2, Pt 1):299–302
22 Charles HW, Black M, Kovacs S, et al. G2 inferior vena cava filter: retrievability and safety. J Vasc Interv Radiol 2009;20(8): 1046–1051
23 Lynch FC, Kekulawela S. Removal of the G2 filter: differences between implantation times greater and less than 180 days. J Vasc Interv Radiol 2009;20(9):1200–1209
24 Marquess JS, Burke CT, Beecham AH, et al. Factors associated with failed retrieval of the Günther Tulip inferior vena cava filter. J Vasc Interv Radiol 2008;19(9):1321–1327
25 Smouse HB, Rosenthal D, Thuong VH, et al. Long-term retrieval success rate profile for the Günther Tulip vena cava filter. J Vasc Interv Radiol 2009;20(7):871–877, quiz 878
26 Wicky S, Doenz F, Meuwly J-Y, Portier F, Schnyder P, Denys A. Clinical experience with retrievable Günther Tulip vena cava filters. J Endovasc Ther 2003;10(5):994–1000
27 Xiao L, Huang DS, Shen J, Tong JJ. Introducer curving technique for the prevention of tilting of transfemoral Günther Tulip inferior vena cava filter. Korean J Radiol 2012;13(4):483–491
28 Greenfield LJ, Peyton R, Crute S, Barnes R. Greenfield vena caval filter experience: late results in 156 patients. Arch Surg 1981; 116(11):1451–1456
29 Messmer JM, Greenfield LJ. Greenfield caval filters: long-term radiographic follow-up study. Radiology 1985;156(3):613–618
30 Kinney TB, Rose SC, Weingarten KE, Valji K, Oglevie SB, Roberts AC. IVC filter tilt and asymmetry: comparison of the over-the-wire stainless-steel and titanium Greenfield IVC filters. J Vasc Interv Radiol 1997;8(6):1029–1037
31 Johnson SP, Raiken DP, Grebe PJ, Diffin DC, Leyendecker JR. Single institution prospective evaluation of the over-the-wire Greenfield vena caval filter. J Vasc Interv Radiol 1998;9(5):766–773
32 Sweeney TJ, Van Aman ME. Deployment problems with the titanium Greenfield filter. J Vasc Interv Radiol 1993;4(5):691–694
33 Wittenberg G, Kueppers V, Tschammler A, Scheppach W, Kenn W, Hahn D. Long-term results of vena cava filters: experiences with the LGM and the Titanium Greenfield devices. Cardiovasc Intervent Radiol 1998;21(3):225–229
34 Nicholson AA, Ettles DF, Paddon AJ, Dyet JF. Long-term follow-up of the bird's nest IVC filter. Clin Radiol 1999;54(11):759–764
35 McLoney ED, Krishnasamy VP, Castle JC, Yang X, Guy G. Complications of Celect, Günther tulip, and Greenfield inferior vena cava filters on CT follow-up: a single-institution experience. J Vasc Interv Radiol 2013;24(11):1723–1729
36 Hoffer EK, Mueller RJ, Luciano MR, Lee NN, Michaels AT, Gemery JM. Safety and efficacy of the Gunther Tulip retrievable vena cava filter: midterm outcomes. Cardiovasc Intervent Radiol 2013; 36(4):998–1005
37 Olorunsola OG, Kohi MP, Fidelman N, et al. Caval penetration by retrievable inferior vena cava filters: a retrospective comparison of Option and Günther Tulip filters. J Vasc Interv Radiol 2013; 24(4):566–571
38 Zhou D, Spain J, Moon E, Mclennan G, Sands MJ, Wang W. Retrospective review of 120 Celect inferior vena cava filter retrievals: experience at a single institution. J Vasc Interv Radiol 2012;23(12):1557–1563
39 Sangwaiya MJ, Marentis TC, Walker TG, Stecker M, Wicky ST, Kalva SP. Safety and effectiveness of the celect inferior vena cava filter: preliminary results. J Vasc Interv Radiol 2009;20(9):1188–1192
40 Greenfield LJ, Cho KJ, Proctor M, et al. Results of a multicenter study of the modified hook-titanium Greenfield filter. J Vasc Surg 1991;14(3):253–257
41 Ferris EJ, McCowan TC, Carver DK, McFarland DR. Percutaneous inferior vena caval filters: follow-up of seven designs in 320 patients. Radiology 1993;188(3):851–856
42 Greenfield LJ, Cho KJ, Pais SO, Van Aman M. Preliminary clinical experience with the titanium Greenfield vena caval filter. Arch Surg 1989;124(6):657–659
43 Hoppe H, Nutting CW, Smouse HR, et al. Günther Tulip filter retrievability multicenter study including CT follow-up: final report. J Vasc Interv Radiol 2006;17(6):1017–1023
44 Millward SF, Peterson RA, Moher D, et al. LGM (Vena Tech) vena caval filter: experience at a single institution. J Vasc Interv Radiol 1994;5(2):351–356
45 Crochet DP, Brunel P, Trogrlic S, Grossetëte R, Auget J-L, Dary C. Long-term follow-up of Vena Tech-LGM filter: predictors and frequency of caval occlusion. J Vasc Interv Radiol 1999;10(2, Pt 1):137–142
46 Corriere MA, Sauve KJ, Ayerdi J, et al. Vena cava filters and inferior vena cava thrombosis. J Vasc Surg 2007;45(4):789–794
47 Simon M, Athanasoulis CA, Kim D, et al. Simon nitinol inferior vena cava filter: initial clinical experience. Work in progress. Radiology 1989;172(1):99–103
48 Kim D, Edelman RR, Margolin CJ, et al. The Simon nitinol filter: evaluation by MR and ultrasound. Angiology 1992;43(7):541–548
49 Grassi CJ, Matsumoto AH, Teitelbaum GP. Vena caval occlusion after Simon nitinol filter placement: identification with MR imaging in patients with malignancy. J Vasc Interv Radiol 1992; 3(3):535–539
50 Food and Drug Administration. Removing Retrievable Inferior Vena Cava Filters: FDA Safety Communication. Published 2014. Available at: http://www.fda.gov/MedicalDevices/Safety/AlertsandNotices/ucm396377.htm. Accessed January 1, 2015
51 Morales JP, Li X, Irony TZ, Ibrahim NG, Moynahan M, Cavanaugh KJ Jr. Decision analysis of retrievable inferior vena cava filters in patients without pulmonary embolism. J Vasc Surg Venous Lymphat Disord 2013;1(4):376–384
52 Angel LF, Tapson V, Galgon RE, Restrepo MI, Kaufman J. Systematic review of the use of retrievable inferior vena cava filters. J Vasc Interv Radiol 2011;22(11):1522–1530.e3
53 Meyer A, Schönleben F, Heinz M, Lang W. Perforated inferior vena cava filters as the cause of unclear abdominal pain. Ann Vasc Surg 2013;27(3):354.e9–354.e12
54 Pellerin O, di Primio M, Sanchez O, Meyer G, Sapoval M. Successful retrieval of 29 ALN inferior vena cava filters at a mean of 25.6 months after placement. J Vasc Interv Radiol 2013;24(2):284–288
55 Pellerin O, Barral FG, Lions C, Novelli L, Beregi JP, Sapoval M. Early and late retrieval of the ALN removable vena cava filter: results from a multicenter study. Cardiovasc Intervent Radiol 2008;31(5): 889–896
56 Kuo WT, Robertson SW, Odegaard JI, Hofmann LV. Complex retrieval of fractured, embedded, and penetrating inferior vena cava filters: a prospective study with histologic and electron microscopic analysis. J Vasc Interv Radiol 2013;24(5):622–630. e1, quiz 631
57 Mismetti P, Rivron-Guillot K, Quenet S, et al. A prospective long-term study of 220 patients with a retrievable vena cava filter for secondary prevention of venous thromboembolism. Chest 2007; 131(1):223–229

58 Imberti D, Bianchi M, Farina A, Siragusa S, Silingardi M, Ageno W. Clinical experience with retrievable vena cava filters: results of a prospective observational multicenter study. J Thromb Haemost 2005;3(7):1370–1375
59 Caronno R, Piffaretti G, Tozzi M, et al. Mid-term experience with the ALN retrievable inferior vena cava filter. European journal of vascular and endovascular surgery: the official journal of the European Society for Vascular Surgery 2006;32(5): 596–9
60 Zhu X, Tam MDBS, Bartholomew J, Newman JS, Sands MJ, Wang W. Retrievability and device-related complications of the G2 filter: a retrospective study of 139 filter retrievals. J Vasc Interv Radiol 2011;22(6):806–812
61 Oliva VL, Perreault P, Giroux M-F, Bouchard L, Therasse E, Soulez G. Recovery G2 inferior vena cava filter: technical success and safety of retrieval. J Vasc Interv Radiol 2008;19(6):884–889
62 Kuo WT, Robertson SW. Bard Denali IVC filter fracture and embolization resulting in cardiac tamponade: a device failure analysis. Journal of vascular and interventional radiology. J Vasc Interv Radiol 2014; In press
63 Stavropoulos SW, Sing RF, Elmasri F, et al; DENALI Trial Investigators. The DENALI Trial: an interim analysis of a prospective, multicenter study of the Denali retrievable inferior vena cava filter. J Vasc Interv Radiol 2014;25(10):1497–1505, 1505.e1
64 Awh MH, Taylor FC, Lu CT. Spontaneous fracture of a Vena-Tech inferior vena caval filter. AJR Am J Roentgenol 1991;157(1): 177–178
65 Ricco J-B, Dubreuil F, Reynaud P, et al. The LGM Vena-Tech caval filter: results of a multicenter study. Ann Vasc Surg 1995;9(Suppl): S89–S100
66 Murphy TP, Dorfman GS, Yedlicka JW,et al. LGM vena cava filter: objective evaluation of early results. J Vasc Interv Radiol 1991; 2(1):107–115
67 Le Blanche AF, Benazzouz A, Reynaud P, et al. The VenaTech LP permanent caval filter: effectiveness and safety in the prevention of pulmonary embolism–a European multicenter study. Journal of vascular and interventional radiology. J Vasc Interv Radiol 2008; 19(4):509–515
68 Taheri SA, Kulaylat MN, Johnson E, Hoover E. A complication of the Greenfield filter: fracture and distal migration of two struts—a case report. J Vasc Surg 1992;16(1):96–99
69 Carabasi RA III, Moritz MJ, Jarrell BE. Complications encountered with the use of the Greenfield filter. Am J Surg 1987;154(2): 163–168
70 Wingerd M, Bernhard VM, Maddison F, Towne JB. Comparison of caval filters in the management of venous thromboembolism. Arch Surg 1978;113(11):1264–1271
71 Greenfield LJ, Michna BA. Twelve-year clinical experience with the Greenfield vena caval filter. Surgery 1988;104(4):706–712
72 Greenfield LJ, Proctor MC. Twenty-year clinical experience with the Greenfield filter. Cardiovasc Surg 1995;3(2):199–205
73 Greenfield LJ, Proctor MC. The percutaneous greenfield filter: outcomes and practice patterns. J Vasc Surg 2000;32(5):888–893
74 Cho KJ, Greenfield LJ, Proctor MC, et al. Evaluation of a new percutaneous stainless steel Greenfield filter. J Vasc Interv Radiol 1997;8(2):181–187
75 Greenfield LJ, Proctor MC, Cho KJ, et al. Extended evaluation of the titanium Greenfield vena caval filter. J Vasc Surg 1994;20(3): 458–464, discussion 464–465
76 Wang W, Zhou D, Obuchowski N, Spain J, An T, Moon E. Fracture and migration of Celect inferior vena cava filters: a retrospective review of 741 consecutive implantations. J Vasc Interv Radiol 2013;24(11):1719–1722
77 Lyon SM, Riojas GE, Uberoi R, et al. Short- and long-term retrievability of the Celect vena cava filter: results from a multi-institutional registry. J Vasc Interv Radiol 2009;20(11):1441–1448
78 Roehm JO Jr, Johnsrude IS, Barth MH, Gianturco C. The bird's nest inferior vena cava filter: progress report. Radiology 1988;168(3): 745–749
79 Ziegler JW, Dietrich GJ, Cohen SA, Sterling K, Duncan J, Samotowka M. PROOF trial: protection from pulmonary embolism with the OptEase filter. J Vasc Interv Radiol 2008;19(8):1165–1170
80 Oliva VL, Szatmari F, Giroux M-F, Flemming BK, Cohen SA, Soulez G. The Jonas study: evaluation of the retrievability of the Cordis OptEase inferior vena cava filter. J Vasc Interv Radiol 2005;16(11): 1439–1445, quiz 1445
81 Rosenthal D, Swischuk JL, Cohen SA, Wellons ED. OptEase retrievable inferior vena cava filter: initial multicenter experience. Vascular 2005;13(5):286–289
82 Kalva SP, Wicky S, Waltman AC, Athanasoulis CA. TrapEase vena cava filter: experience in 751 patients. J Endovasc Ther 2006; 13(3):365–372
83 Liu WC, Do YS, Choo SW, et al. The mid-term efficacy and safety of a permanent nitinol IVC filter(TrapEase). Korean J Radiol 2005;6(2): 110–116
84 Rousseau H, Perreault P, Otal P, et al. The 6-F nitinol TrapEase inferior vena cava filter: results of a prospective multicenter trial. J Vasc Interv Radiol 2001;12(3):299–304
85 Kalva SP, Marentis TC, Yeddula K, Somarouthu B, Wicky S, Stecker MS. Long-term safety and effectiveness of the "OptEase" vena cava filter. Cardiovasc Intervent Radiol 2011;34(2):331–337
86 Usoh F, Hingorani A, Ascher E, et al. Prospective randomized study comparing the clinical outcomes between inferior vena cava Greenfield and TrapEase filters. J Vasc Surg 2010;52(2):394–399
87 Johnson MS, Nemcek AA Jr, Benenati JF, et al. The safety and effectiveness of the retrievable option inferior vena cava filter: a United States prospective multicenter clinical study. J Vasc Interv Radiol 2010;21(8):1173–1184
88 Smouse HB, Mendes R, Bosiers M, Van Ha TG, Crabtree T, Investigators R; RETRIEVE Investigators. The RETRIEVE trial: safety and effectiveness of the retrievable crux vena cava filter. J Vasc Interv Radiol 2013;24(5):609–621

EXHIBIT 5
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EXHIBIT 6
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EXHIBIT 7
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